MARSH PLANT ASSOCIATIONS OF SOUTH SAN FRANCISCO BAY: 2006 COMPARATIVE STUDY

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December 29, 2006 Project No. 477-28

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EXECUTIVE SUMMARY

Large-scale plant community changes in the remaining marshes of South San Francisco Bay were first observed in the 1970's. Early studies conducted for the South Bay Dischargers Authority in 1984 confirmed those habitat changes. In 1989, as part of a monitoring program required by the San Francisco Bay Regional Water Quality Control Board, the City of San Jose commissioned a more detailed study of the marshes potentially affected by the freshwater discharge from the Water Pollution Control Plant (WPCP). Subsequent mapping studies were conducted in 1991, 1994, and annually thereafter. These studies documented changes in the distribution and aerial extent of salt, brackish and freshwater marsh. This study is the continuation of the WPCP monitoring program.

The 2006 plant association mapping was done on digital 1-meter Multispectral (4-bands) CIR & True Color IKONOS satellite imagery. The entire study area was mapped in the field by H.T. Harvey & Associates plant biologists. The vegetation mapping was then spot-checked by senior biologists. Acreage calculations by plant associations, dominant species and habitat type maps and acreage tables were produced in Geographic Information Systems (GIS) software. Comparisons were made between the 2006 mapping and the 1989 and 2005 mapping.

The total marsh area mapped in 2006 was 1,763 acres for the Main Study Area and 265 acres for the Reference Site. Brackish marsh plant associations dominated the Upper Reaches of the Main Study Area. The Transition Reach segments comprise a mix of brackish and salt marsh while the Lower Reach segments are primarily dominated by salt marsh plant species. Although a similar distribution of habitats is noted in the Reference Area, brackish marsh habitats comprise a much greater proportion there than in the Main Study Area.

The surface area of marsh habitat has increased by 343.6 acres between 1989 and 2006 within the Main Study Area (Upper, Transition and Lower Reaches combined). During the same period, 73.8 acres of new marsh has formed in the Reference Area. This equates to a 26% increase in marsh acreage in the Main Study Area and a 44% increase in marsh acreage in the Reference Area between 1989 and 2006. From 1989 to 2006, a total of 119.6 acres of salt marsh habitat has converted to brackish marsh habitat in the Main Study Area, and 32.1 acres of salt marsh habitat converted to brackish marsh in the Reference Area. However, during the same time period, 32.1 acres of brackish marsh has converted to salt marsh habitat in the Main Study Area and 3.3 acres has converted from brackish marsh to salt marsh habitat in the Reference Area. Therefore, since 1989, 87.5 acres of net conversion from salt marsh to brackish marsh habitat occurred within the Main Study Area and 28.8 acres of net salt marsh to brackish habitat conversion occurred in the Reference Area.

There has been a greater relative percentage in net conversion of salt marsh compared to the overall amount of salt marsh habitat within the Reference Area (35%) than within the Main Study Area (9%). However, when you remove the Lower Reach (which has a large amount of salt marsh and very little relative marsh conversion since 1989) the percent in net conversion of salt marsh in the Transition and Upper Reaches combined is 43%, which more closely matches the net salt marsh conversion (35%) within the Reference Area. By looking at the individual

Reaches we can determine where significant change is taking place. For example, only about 2% of the overall net salt marsh conversion occurs in the Lower Reach, while the Transition Reach accounts for approximately 51% of the overall net salt marsh conversion, and approximately 14% of the overall net salt marsh conversion occurs in the Upper Reach of the Main Study Area. The Reference Reach by comparison accounts for approximately 35% of the overall salt marsh conversion.

Between 1989 and 1999 the relative change in habitat types through time was less in the Main Study Area than in the Reference Area although the rate of new marsh formation in the Main Study Area had exceeded that of the Reference Area. This indicates that much of the conversion of salt marsh habitats within the South San Francisco Bay area was likely driven by large-scale influences affecting the entire system. However, overall gains in salt marsh habitat in the last six years (2001 to 2006) highlights the influence of multiple factors affecting changes in marsh vegetation communities in South San Francisco Bay. Primary among these factors is the increase in sedimentation resulting in the decrease in tidal prism, which may continue to contribute to increase the area of vegetated marsh within the Main Study Area.

Newly formed marsh will also likely be the first marshes to be impacted by any increases in tidal scour related to the restoration of tidal action (breaching) to any salt ponds in the Alviso Complex as part of the South Bay Salt Pond (SBSP) Restoration project. As part of the implementation of the Initial Stewardship Plan for the SBSP Restoration Project, three former salt ponds adjacent to Segments 14, 15, and 21 in the Main Study Area were breached in 2006. The breaching of these ponds may result in increased tidal prism in the Main Study Area, which could result in vegetation shifts unrelated to the WPCP discharges.

Freshwater discharges from the WPCP appear to have influenced plant species distribution within Artesian Slough since the 1970's. This slough begins at the discharge point for the WPCP, and is primarily freshwater marsh habitat. Without the WPCP discharge we would expect that Artesian Slough would consist of a mixture of brackish and salt marsh habitats. However, WPCP discharges have been relatively constant since 1990 while salt marsh conversion has fluctuated.

Significant areas of die-off in alkali bulrush vegetation communities during the past two years in both the Main Study Area and in the Reference area, plus salt to brackish marsh conversion occurring in the Reference Area, indicate that both rainfall and freshwater discharges, in conjunction with changing channel bathymetry in the South Bay, are affecting the plant species distribution of the South Bay marshes. Therefore, it is likely that much of the interannual variation in habitats within the South Bay marshes is due to the on-going resizing of the channels from the reductions in tidal prism in the South Bay, as well as large-scale environmental factors (*e.g.*, variations in annual rainfall patterns and bay salinity, as well as increases in mean sea level).

INTRODUCTION

Large-scale plant community changes in the marshes of South San Francisco Bay were first observed in the 1970's (H. T. Harvey & Associates 1984). Brackish marsh plants were colonizing areas that had previously been vegetated with salt marsh plants. Based upon those observations, causal mechanisms for the vegetation change were reviewed. A potential cause of that change was freshwater input from the San Jose/Santa Clara Water Pollution Control Plant (WPCP).

Early studies confirmed the observed changes in plant species composition (H. T. Harvey & Associates 1984). Efforts were made to determine the extent of these changes through time by examining historical aerial photography (CH2MHill 1989). These studies relied on aerial photographs of different scales, and since they were historical, could not be field-truthed. However, the data indicated that large-scale vegetation changes (both marsh type conversion and new marsh formation) were occurring in the marshes of South San Francisco Bay.

In 1989, as part of a monitoring program required by the San Francisco Bay Regional Water Quality Control Board (RWQCB), the City of San Jose commissioned a more detailed study of the marshes potentially affected by the freshwater discharge from the WPCP (H. T. Harvey & Associates 1990a). Simultaneously, and also at the behest of the RWQCB, the Sunnyvale WPCP commissioned a study of the vegetation of the marshes in Guadalupe and Alviso Sloughs. Both of these studies included the collection of new aerial photography and detailed mapping of dominant plant species in the field. These data now provide the baseline for comparison of changes in plant species distribution in the marshes of South San Francisco Bay.

Subsequent mapping studies were conducted by the City of San Jose in 1991, 1994, and annually thereafter. These studies documented changes in the distribution and extent of salt, brackish and freshwater marsh (CH2MHill 1989, H.T. Harvey & Associates 1990a, 1990b, 1991, 1995, 1997, 1998, 1999, 2000, 2001a, 2002, 2003, 2004 and 2005). Yearly mapping has been important in detecting inter-annual vegetation shifts that might not have been detectable otherwise. A similar study in Georgia by Higginbotham and others (2004) detected significant inter-annual changes over a 40-year time period. Starting in 1994 it was recognized that the Alviso Slough mapping, conducted for the Sunnyvale WPCP, could serve as a reference area for the City of San Jose's vegetation mapping. To use Alviso Slough as a reference area for these studies, it was assumed that discharges from the WPCP did not flow 'upstream' into Alviso Slough, and directly impact its marshes. This assumption is supported by a dilution study performed in Alviso Slough that found increased dilution of discharge waters with increased distance from the WPCP discharge site and very little entrainment of WPCP waters into Alviso Slough (CH2MHILL 1990). This assumption is also addressed in the mapping analysis. Furthermore, Alviso Slough does receive direct freshwater discharge from the Guadalupe River; just as the Main Study Area receives freshwater discharge from Coyote Creek. Therefore, all mapping efforts since 1995 have included the Main Study Area and this additional reference area (Alviso Slough).

The dominant plant species of tidal salt marshes in South San Francisco Bay include pickleweed (mainly *Salicornia virginica*) and cordgrass (*Spartina* sp.). Pickleweed dominated salt marsh provides habitat for a unique assemblage of animal species including the federally and state-endangered salt marsh harvest mouse (*Reithrodontomys raviventris raviventris)* and California Clapper Rail (*Rallus longirostris obsoletus*). (An expanded description of the habitat requirements for these wildlife species can be found in the Discussion section at the end of the report.) Therefore, it is important to determine the area of vegetation change as well as to identify the factors responsible for the observed conversion of salt marsh habitat to brackish and freshwater marsh habitats. Furthermore, it is important to understand the extent that this conversion may be caused by natural, region-wide environmental change versus anthropogenic changes such as freshwater discharge from the WPCP and dry-weather releases from local reservoirs.

Research has shown that a number of variables control the distribution of plant species in coastal marshes. The most obvious of these factors, surface water and soil salinity, have been shown to correlate significantly with vegetation distributions (Reardon 1996, Callaway and Sabraw 1994, Allison 1992, Callaway et al. 1989, Zedler 1983, Zedler and Beare 1986). For example, Zedler (1983) documented the conversion of a pickleweed-dominated salt marsh to a cattail-dominated (*Typha domingensis*) freshwater marsh along the San Diego River. She found that the conversion was highly correlated with prolonged reservoir discharges that continued well beyond the normal rainy season, thereby decreasing salinities. Salinity tolerance is also important in relation to species life history stages. The timing of fresh or saline inputs my also affect plant species distributions and can have an effect on seed germination and growth.

However, many other factors also influence marsh species composition including: depth and duration of flooding over the marsh surface (Webb and Mendelssohn 1996, Webb et al. 1995, Pennings and Callaway 1992, Mendelssohn and McKee 1988, Mall 1969), accumulation of phytotoxins such as hydrogen sulfide in marsh soils (Webb and Mendelssohn 1996, Webb et al. 1995, Koch and Mendelssohn 1989, DeLaune et al. 1983, King et al. 1982), interstitial nutrient concentrations (Koch et al. 1990, Bradley and Morris 1980, Koch and Mendelssohn 1989, Morris 1980), and soil mineral and organic matter content (Nyman et al. 1990, DeLaune et al. 1979). Natural variability in abiotic factors such as precipitation, tidal fluctuation, and evapotranspiration, as well as anthropogenic changes to those factors such as freshwater discharges, non-point source pollution (nutrients and sediments), and regional/global climate changes (drought, temperature, sea level) influence these variables. Alexander and Dunton (2002) found that timing and quantity of freshwater inputs strongly dictated halophyte response to precipitation in two marshes in Louisiana. Warren and Niering (1993) found increased flooding frequency from sea level rise altered tidal marsh plant associations in the northeastern United States. Wisser et al (2006) used an 18-year record of end-of season biomass to evaluate multiple stressor effects (flooding duration, salinity, air temperature, precipitation deficits, nutrient availability and cloud cover) in Louisiana salt marshes and found that when surface water and cloud cover were optimal, larger flooding durations reduced peak biomass.

Competition between different plant species (interspecific) with similar environmental tolerances also influences their distributions. Although environmental tolerance and competitive ability are inversely related (Grace and Wetzel 1981, Zedler 1982, Bertness 1991), competition still plays a role among species with similar tolerances. For example, Zedler (1982) found that competitive interactions occur in salt marshes, and concluded that pickleweed does compete with cordgrass for light and to some extent, nutrients. Leininger (2006) used a model to examine rain, drought, and disturbance scenarios along with marsh conditions at three marsh study sites in San Francisco Bay and found that invasion potential of perennial peppergrass (*Lepidium latifolium)* varies with site disturbance and rainfall conditions. In particular, perennial peppergrass spread was inhibited in years of increased moisture and also with increased salinity.

This study continues the vegetation monitoring of the marshes in South San Francisco Bay that began in 1989. The vegetation mapping conducted by this study determines the spatial location and extent of change in plant communities. This study does not monitor or experimentally manipulate variables that can be responsible for the observed changes. Therefore, the vegetation mapping of the marshes in South San Francisco Bay tracks any changes over time; comparisons are limited to interannual rates of change between the Main Study Area and a Reference area.

SURVEY METHODS

STUDY AREA

For the purposes of data collection and analysis, we divided the study area into 28 segments as defined in the 1989 study (H. T. Harvey & Associates 1990a; Figure 1). We then sub-divided the study area into four Reaches (Upper Reach segments, Transition Reach segments, Lower Reach segments, and Alviso Slough segments [Reference Reach]) to provide a more easily comprehensible method of analyzing the data and presenting the results (Figure 1). The Upper (approximately 450 acres), Transition (approximately 390 acres), and Lower Reach (approximately 840 acres) segments, referred to as the Main Study Area are located within the Coyote Creek watershed and include Segments 1-5 and 8-26 (Figure 1). Segments 27-30 (Reference Area - approximately 260 acres) are located along the lower Guadalupe River, also known as Alviso Slough (Figure 1). This study assumes that the WPCP discharge does not significantly influence the Reference Area, and therefore provides a suitable control site for documenting vegetation changes in South San Francisco Bay.

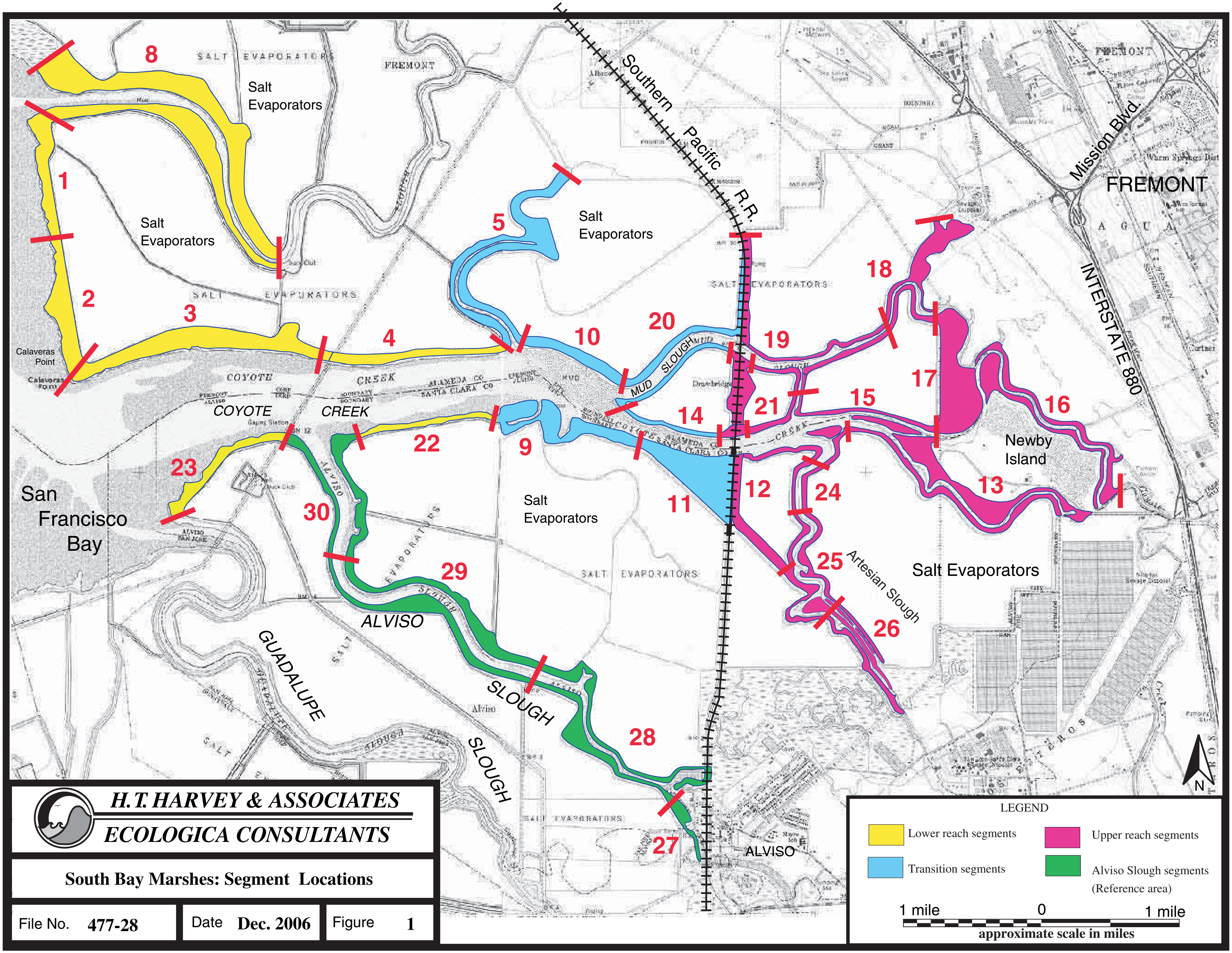
BASE IMAGERY

The City of San Jose acquired IKONOS imagery from a satellite pass that occurred at 11:02 a.m. on June 30, 2006. The tidal elevation at this time was -0.1 feet MLLW near the Calaveras Point Station. The 1-meter Multispectral (4-bands) color infrared (CIR) & True Color orthorectified IKONOS satellite imagery is projected in StatePlane NAD83 Zone III (feet).

VEGETATION ASSOCIATION MAPPING AND AREA CALCULATIONS

Habitat mapping was based upon the imagery obtained and completed at a scale to 1:2400 (one inch = 200 feet) using the IKONOS imagery as a base layer. Habitat mapping was assisted using two laptop computers (Panasonic Toughbook 18) equipped with geographic information systems (GIS) software (ArcView 9.1). These computers and software allow the IKONOS imagery to be used for mapping in the field or in the office.

The initial mapping was conducted in-house; habitat boundaries and classifications were identified using the IKONOS imagery and was based on the signatures of the photographic imagery. Topographic features, marsh boundaries, and tentative habitat types (based on photographic signatures) were mapped in the office prior to field visits.



South Bay Marshes: Segment Locations

File No. 477-28	Date Dec. 2006	Figure 1

Complete ground-truthing of the preliminary mapping was conducted during site visits to the project area during July and August 2006. Marsh vegetation was observed primarily from areas directly adjacent to the marshes in order to maintain consistency with the methods employed in previous years and also to follow U.S. Fish and Wildlife Service (USFWS) guidelines and regulations. Therefore, marshes were observed primarily from levee roadways, railroad beds, unimproved salt pond levees and Pacific Gas and Electric (PG&E) walkways. Due to very recent work on the levees by Cargill on some of the Mowry salt ponds, Segments 1 and 2 were primarily observed via boat. Boat access also increased observation of the marsh edge in Segments 3, 4, and 8. Only when necessary and allowed by USFWS regulations were vegetation associations verified by walking in those marshes areas that were not clearly visible from adjacent levees and upland areas. Access via foot into the marshes of Segments 3, 11, and 17 was conducted in conjunction with the USFWS approved salt marsh harvest mouse trapping that occurred in August and September of 2006. Access to the Study Area was obtained from the USFWS San Francisco Bay National Wildlife Refuge (Clyde Morris 510.792.4275), Cargill Salt Division, Newark, CA (Pat Mapelli 510.790.8610), and the Newby Island Landfill (Mr. Gil Cheso 408.945.2802).

The GIS database was downloaded and backed-up weekly. The digitized boundaries of habitat areas were reviewed for consistency and quality. Plant association acreages and color-coded figures for the entire Study Area were generated in GIS (ArcView 9.1). Plant association acreages and color-coded figures for the entire Study Area were generated by GIS systems ArcInfo and ArcView.

VEGETATION ASSOCIATION CATEGORIZATION METHODS

Any species that occurred as a dominant, co-dominant or sub-dominant as defined below, in any portion of the study area was mapped. For the purposes of this study a dominant species had a percent cover of 51-100%, co-dominant species have roughly equal percent coverage, and sub-dominant species have between 15 and 49 percent cover.

Each species was then assigned to a vegetation association comprised of one dominant, a dominant and subdominant, or two or more co-dominant species. The three types of vegetation associations are described below:

Dominant – An area that consists of one dominant species that comprises approximately 85-100% of the cover is named solely for that species, so that the vegetation association called pickleweed consists of from 85-100% pickleweed and less than 15% of other unspecified species.

Dominant/sub-dominant – If one species comprises between approximately 51-85% of the cover in a particular area, and another species comprises 15-49% cover in that same area, then this is dominant/sub-dominant vegetation association. The association is named for both species, with the more abundant species listed first. The category called pickleweed/alkali bulrush could therefore consist of 51-85% cover of pickleweed and 15-49% cover of alkali bulrush.

Co-dominant – One co-dominant association was identified in 2006: Pickleweed-Cordgrass Mix. This species mix represents approximately equal amount of each species and their combined total coverage exceeds 85%.

The upland species category consists of species not considered by the USFWS (1988) to be wetland indicators. These include ruderal species such black mustard (*Brassica nigra*), ripgut grass (*Bromus diandrus*), bristly ox-tongue (*Picris echioides*), sweet fennel (*Foeniculum vulgare*), and coyote brush (*Baccharis pilularis*). The peripheral halophyte category consists of a patchwork of species that occur along salt marsh edges, such as levee slopes. This mixture, in which no one species generally exceeds 15% of the cover, includes pickleweed and various peripheral halophyte species such as alkali heath (*Frankenia salina*), Australian saltbush (*Atriplex semibaccata*) and slender-leaved iceplant (*Mesembryanthemum nodiflorum*).

Plant species associations were grouped into dominant species categories (*e.g.*, alkali bulrush/peppergrass association is an alkali bulrush dominant species category). These dominant species categories were then assigned to one of four habitat types: salt marsh, brackish marsh, freshwater marsh and upland. A number of assumptions about grouping dominant species into appropriate habitat types were made. These include:

- Relative salt tolerance of dominant plant species;
- Edaphic characteristics of the South Bay Marshes that may control plant species distribution;
- Historic relationships within this study, and;
- Relationships between dominant plant species and wildlife use.

Certain plant species for which salinity tolerance data are lacking (*e.g*. spearscale) were categorized into habitat types based on relative location in the marsh plain or known wildlife use. This assumption and the potential uncertainties related to assigning plant species to habitat type categories has been understood throughout the study period and was stated in the 1989 (baseline) study (H. T. Harvey & Associates 1990a). The habitat classification scheme first used in the baseline study is carried through to this study to collect comparable data.

AREA COMPARISONS

Analysis of potential marsh conversion within the Main Study and Reference Areas involved a multi-step process that began at a total marsh area level and proceeded to a more specific, segment-level analysis. The first task involved comparing the relative acreage change in marsh type and dominant species categories between years. The current year's results are compared to baseline year 1989. When a significant shift in marsh acreage occurred, the dominant species categories responsible for that shift were also identified.

In order to identify where significant acreage changes had occurred, the marsh was divided into four areas based upon segment location: Upper, Transition, Lower and Reference (Alviso Slough) (Figure 1) as described earlier. These are outlined in Table 1.

Table 1. South Bay Marsh Segments and Their Reaches.

Reaches	Segments
Lower (Mouth of Coyote Creek)	1, 2, 3, 4, 8, 22 and 23
Transition (Drawbridge)	5, 9, 10, 11, 14 and 20
Upper (Newby Island)	12, 13, 15, 16, 17, 18, 19, 21, 24, 25 and 26
Reference (Alviso Slough)	27, 28, 29 and 30

A comparison of marsh habitat acreage data from all years (1989, 1991, 1994, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005 and 2006) by location (Reach) was also conducted to compare trends between Reaches. The final step in the analysis overlaid the data from the 1989 mapping onto 2006 data in ArcView to determine, with confidence, the location and size of change in marsh area and habitat type. Dominant species and habitat maps were produced for each of the four segment locations. The maps were produced from an ArcView database and the full mapping for all segments by plant species association is available electronically.

EDAPHIC CHARACTERISTICS

In 2005, several small areas of dead alkali bulrush were observed during mapping. In 2006, substantial areas of dead vegetation were observed and mapped within both the Reference Area and the Main Study Area (formerly alkali bulrush and pickleweed habitats). Photo-documentation of several of these sites is included in Appendix F (Figures F1-F6). In order to better understand the processes resulting in the dead vegetation, soil bulk density and interstitial soil salinity cores were sampled at six locations within the Reference Area in September 2006 (Appendix G, Figure G-1). Four of the selected sites were permanent stations previously used for sampling edaphic characteristics in 2000 and 2001 (H. T. Harvey & Associates 2002). Of these six samples, three were collected in areas with live vegetation and three in areas with dead vegetation. Each soil core consisted of a 15cm long core with a diameter of 5.25cm. A depth of 15cm was chosen since this is the approximate depth of the root zone for most tidal wetland plants. Once the cores were extracted, they were delivered directly to the laboratory for analysis. H. T. Harvey & Associates performed the field collection and data analysis, and Soil Control Lab completed the soil analysis.

Interstitial Salinity and pH

Interstitial soil salinity and pH cores were collected and analyzed in September 2006. To obtain porewater, the sediment cores were centrifuged in a refrigerated ultra-sonic centrifuge (Sorvall Super T21) at 6000 RCF (relative centrifugal force) for approximately 15 minutes each. Some samples required a slightly longer centrifuge to obtain sufficient porewater. Conductivity was measured on the undiluted porewater using a Cole Palmer 19101-00 Conductivity Meter. Conductivity readings were then converted to salinity (parts per thousand) using the USGS algorithm. Porewater pH was measured on the undiluted samples using a Fisher Accumet 15 pH meter.

Secondary Indicators of Inundation

Soil cores were analyzed for secondary indicators of inundation by examining the soil for redoximorphic features including the presence of gleying and oxidized rhizospheres. Soil color was determined using a Munsell Color Book. The type, density, and distribution of these features can provide important information regarding the frequency and duration of soil saturation.

Soil Bulk Density

Soil bulk density samples were collected and analyzed in September 2006. The soil bulk density samples were dried at 105º C for at least 48 hours, longer if necessary, to drive off all of the water. The cores were then weighed using a Mettler PJ3000 top loading balance. Bulk density was calculated by dividing the weight by the known volume of the sampling cylinder, typically expressed as g/cm^3.

RESULTS

The vegetation mapping results can be found in the detailed habitat maps and raw data in the Appendices of this report:

- Appendix A. Vegetation and Marsh Habitat Maps from 2006
- Appendix B. Spatial Analysis (marsh conversion and gain/loss) from 1989 to 2006
- Appendix C. Detailed Acreage Matrices by Segment and Species
- Appendix D. Plant List of Species Observed During Vegetation Mapping
- Appendix E. Dominant Species Categories, Marsh Type and Vegetation Associations for 1989 and 2006.

GENERAL SPECIES DISTRIBUTION, DOMINANT SPECIES CATEGORY AND HABITAT ACREAGES FOR 2006

Main Study Area

This year, 67 overall vegetation associations (*e.g.*, alkali bulrush/peppergrass) were mapped. For the purposes of this report, the vegetation associations were grouped by dominant species into 17 vegetation categories (*e.g.*, alkali bulrush) (Figures A1-A4). The spatial distribution of dominant plant species and habitat types (see Appendix E for habitat classifications) for the 2006 data are presented in Appendix A for each of the four marsh Reaches within the Main Study Area (figure scales vary). The acreages of habitat types and associated dominant plant species for the Main Study Area are shown in Table 2. The dominant plant species within the Main Study Area are alkali bulrush and pickleweed (Table 2); these two species comprise approximately 63% of the marsh within the Main Study Area.

The segments within the Upper Reach (Appendix A, Figures A-3 and A-7) consist primarily of brackish marsh associations dominated by either pure stands or mixtures of alkali bulrush, peppergrass (*Lepidium latifolium*), and spearscale (*Atriplex triangularis*). The segments within the Lower Reach (nearest San Francisco Bay; Appendix A, Figures A-1 and A-5) are comprised primarily of single-species stands or mixtures of the salt marsh plant species dominated by pickleweed and cordgrass. Although cordgrass and pickleweed are most abundant in the Lower Reach segments, both occur at low abundance even in the furthest upstream segments (although sometimes in patches too small to map). Conversely, peppergrass is most abundant in the Upper Reach segments, but is found throughout most of the Main Study Area (Appendix A, Figures A-1 through A-3). Alkali bulrush occurs throughout the Main Study Area and is the dominant plant species of brackish marsh associations in South San Francisco Bay. The Transition Reach, intermediate to the furthest upstream and downstream Reaches, supported significant amounts of both salt and brackish species, which sometimes occurred in mixed associations (both brackish and salt marsh plant species) (Appendix A, Figures A-2 and A-6).

Table 2. Summary of Acreages of the Main Study Area by Dominant Species Categories for Each Habitat Type for 2006.

Dominant Species Category	2006 (Acres)
Salt Marsh Categories	
Cordgrass	171.9
Pickleweed	645.3[a]
Pickleweed-Cordgrass Mix	95.1
Alkali Heath	11.2
Gumplant	27.8
Jaumea	2.0
Saltgrass	0.2
Peripheral Halophytes	26.3
Sub-Total	**979.8**
Brackish Marsh Categories	
Alkali Bulrush	473.2[b]
Peppergrass	149.6
Spearscale	58.7
Sub-Total	**681.5**
Freshwater Marsh Categories	
California Bulrush	77.2
Cattail	24.6
Misc. Others	<0.1
Sub-Total	**101.9**
TOTAL	**1,763.2**

[a]Total includes 6.8 acres of dead pickleweed in Segment 5

[b]Total includes 11.3 acres of dead alkali bulrush in Segment 13

Reference Area (Alviso Slough)

The spatial distribution of dominant plant species and marsh habitat types by Reach in the Reference Area are presented in Appendix A (Figures A-4 and A-8). The 2006 plant association areas for Alviso Slough are presented in Table 3. Plant species within the Reference Area have a general distribution similar to the Main Study Area in terms of a progression from freshwater to brackish and salt marsh species extending from upstream to the confluence with Coyote Creek. However, instead of pickleweed, alkali bulrush is the dominant plant species within the Reference Area. In earlier years, brackish marsh habitat comprised nearly three times the area of salt marsh habitat. However, salt marsh habitat in Alviso Slough increased gradually since 2000, largely in the form of new marsh created near the confluence with Coyote Creek. Much of this new marsh at the mouth of Alviso Slough was dominated by cordgrass in recent years and this continues to be the case in 2006. Previous mapped areas of annual pickleweed (*Salicornia europaea*) in this area in 2004 have been primarily replaced by cordgrass.

Brackish marsh associations occur throughout Alviso Slough. Patches of alkali bulrush occur as far downstream as Segment 30 (near the confluence with Coyote Creek). Freshwater marsh associations are concentrated in the upstream portions of the slough (nearest the Union Pacific Railroad [UPRR] crossing) and salt marsh associations dominate the downstream areas.

In 2005, a dieback of approximately 3-5 acres of alkali bulrush was observed in a large marsh plain on the slough about 4,000 feet downstream from the Alviso Marina. Additional small patches of dieback were also noted throughout the Main Study Area as well. Because no species replacement or conversion occurred in these areas, they were mapped in 2005 as alkali bulrush habitats. In 2006, these areas expanded instead of recovering as anticipated. Additional large patches of dead vegetation (primarily alkali bulrush or alkali bulrush vegetation associations) were mapped in the Reference Area in Segments 27, 28, and 29, as well as in the Main Study Area in Segment 5. Dead vegetation also occurred in pickleweed dominated habitat in Segment 13 of the Main Study Area.

Table 3. Summary of Acreages of the Reference Area (Alviso Slough) by Dominant Species Categories for Each Habitat Type for 2006.

Dominant Species Category	2006 (Acres)
Salt Marsh Categories	
Cordgrass	37.3
Pickleweed	38.0
Peripheral Halophytes	6.2
Sub-Total	**81.5**
Brackish Marsh Categories	
Alkali Bulrush	83.6[a]
Peppergrass	43.9
Spearscale	14.9
Sub-Total	**142.4**
Freshwater Marsh Categories	
California Bulrush	22.8
Cattail	17.4
Smartweed	0.3
Sub-Total	**40.5**
TOTAL	**264.5**

[a]Total includes 24.0 acres of dead alkali bulrush in Segments 27, 28, and 29 Summary

Brackish marsh plant associations dominated the Upper Reach of the Main Study Area as well as the Reference Reach. The Transition Area comprises both salt (37%) and brackish (63%) marsh habitats. Only the Lower Reach segments remain primarily dominated by salt marsh plant species. A similar distribution of habitats is noted in the Reference Area; brackish marsh habitats dominate a greater proportion of the Reference Area (61%), than salt (30%) or freshwater (9%) habitats.

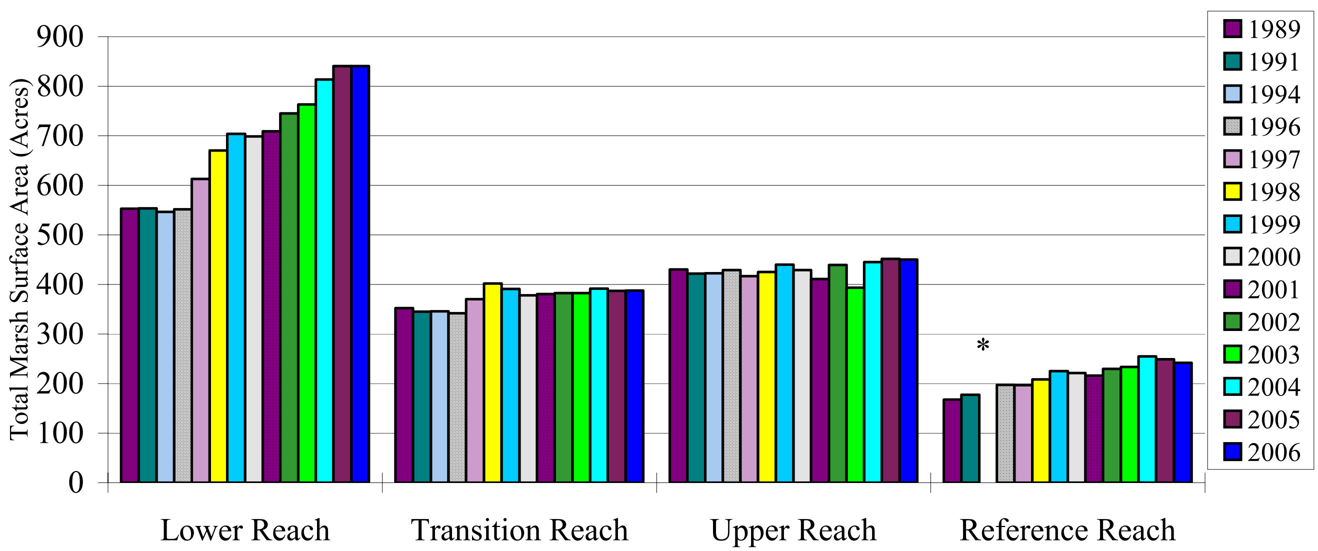
TEMPORAL AND SPATIAL CHANGES IN MARSH HABITAT ACREAGES FROM 1989 THROUGH 2006

This comparison does not include data from segments 24, 25 and 26 (Artesian Slough) of the Main Study Area and segment 27 (vicinity of the Gold Street Bridge) of the Reference Area since those segments were not mapped in 1989. Additionally, the Reference Area was not mapped in 1994; therefore only data from the Main Study Area in 1994 is included in the temporal and spatial evaluation. Data from 1991, 1994 and 1996 – 1999 are not derived from orthorectified images. In 2003, baseline data (1989) was digitized and rectified to the 2001 orthophotos to improve area comparisons and precision of the baseline data (H.T. Harvey & Associates 2003).

New Marsh Formation (Salt, Brackish, and Freshwater Marsh Combined)

Marsh area remained relatively stable from 1989 to 1996 in the Main Study Area (Figure 2). The formation of new marsh habitat in the Main Study Area occurred primarily between 1996 and 2006 in the Lower Reach and between 1996 and 1998 in the Transition Reach (Figure 2). Gains in marsh area between 1989 and 2006 were greatest in the Lower Reach (approximately 306 acres), while just over 55 acres of new marsh formation occurred in the Transition Reach. The majority of new marsh formation occurred in the Lower Reach along the north and south sides of Coyote Creek, immediately upstream of Calaveras Point. Marsh area increased steadily in the Lower Reach from 1996 through 2005 with a slight decrease occurring between 1999 and 2000. There was little new marsh created between 2005 and 2006 (Figure 2). In contrast, in the Transition Reach marsh area increased in 1997 and 1998 but decreased slightly in 1999, 2000 and 2001 (Figure 2). The marsh area in the Transition Reach then remained stable from 2001 to 2006. Compared to the Lower and Transition Reaches, the surface area of marsh in the Upper Reach remained relatively stable (apart from a brief decline in 2003) from 1989 to 2006 (Figure 2).

Figure 2. Total Marsh Acreage Comparison between 1989 and 2006, by Reach.



*No data collected in 1994 within Reference Area.

A trend of increasing marsh area is apparent from 1989 through 1999 in the Reference Area (Figure 2). However, a decline in total marsh acreage in the Reference Area occurred between 1999 and 2001 and this decline was followed by annual increases in marsh area from 2001 to 2004, with slight declines in 2005 and 2006.

Total marsh area in both the Lower Reach and Transition Reach of the Main Study Area remained stable with 2005 levels. Total marsh area in the Upper Reach also remained stable between 2005 and 2006. Within the Main Study Area 2006 (Upper, Transition and Lower Reaches Combined) the surface area of marsh habitat increased by 343.6 acres between 1989 and 2006 (Table 4). During the same period, 73.8 acres of new marsh formed in the Reference Area (Table 5). This equates to a 26% increase in marsh acreage in the Main Study Area and a 44% increase in marsh acreage in the Reference Area between 1989 and 2006.

Table 4. Summary of Acreages of the Main Study Area[a] by Dominant Species Categories for Each Habitat Type for 1989, 2005, 2006 and Percent Change from 1989-2006.

Dominant Species Category	1989 (Acres)	2005 (Acres)	2006 (Acres)	Percent Change (1989-2006)
Salt Marsh Categories				
Cordgrass	84.2	154.8	172.0	104%
Pickleweed	669.1	682.2	644.4[b]	4%
Pickleweed-Cordgrass Mix[c]	-	77.4	95.1	-
Alkali Heath[c]	-	11.9	11.2	-
Gumplant[c]	-	28.4	27.8	-
Peripheral Halophytes	25.6	21.6	24.0	-6%
Misc Others	0.1	1.3	2.2	1,200%
Sub-Total	**779.0**	**977.6**	**976.7**	**25%**
Brackish Marsh Categories				
Alkali Bulrush	489.6	481.1	462.3[d]	-6%
Peppergrass	66.1	154.0	140.4	112%
Spearscale[c]	-	26.0	58.3	-
Sub-Total	**555.7**	**661.1**	**661.2**	**19%**
Freshwater Marsh Categories				
California Bulrush	-	23.7	25.0	-
Cattail	-	10.1	14.7	-
Misc. Others	-	<0.1	<0.1	-
Sub-Total	-	**33.8**	**39.7**	-
TOTAL	**1334.7**	**1672.5**	**1678.3**	**26%**

[a]Comparison consists of segments 1-5 and 8-23 only, since segments 24-26 were not mapped in 1989

[b]Dead pickleweed was included in this acreage

[c]Not a dominant species category in 1989

[d]Dead alkali bulrush was included in this acreage

Table 5. Summary of Acreages of the Reference Area (Alviso Slough)[a] by Dominant Species Categories for Each Habitat Type for 1989, 2005, 2006 and Percent Change from 1989-2006.

Dominant Species Category	1989 (Acres)	2005 (Acres)	2006 (Acres)	Percent Change (1989-2006)
Salt Marsh Categories				
Cordgrass	28.3	34.7	37.3	32%
Pickleweed	43.6	40.3	37.3	-14%
Peripheral Halophytes	3.1	4.3	5.9	90%
Misc. Others	-	-	0.1	-
Sub-Total	**75.0**	**79.3**	**80.5**	**7%**
Brackish Marsh Categories				
Alkali Bulrush	72.3	104.8	80.1[b]	11%
Peppergrass	20.4	44.3	43.7	114%
Spearscale[c]	-	5.0	14.9	-
Sub-Total	**92.7**	**154.1**	**138.7**	**50%**
Freshwater Marsh Categories				
California Bulrush	0.3	13.6	16.0	5,233%
Cattail	-	2.0	6.5	-
Misc. Others	-	0.1	0.1	-
Sub-Total	**0.3**	**15.6**	**22.6**	**7,433%**
TOTAL	**168.0**	**249.0**	**241.8**	**44%**

[a]Comparison consists of segments 28-30.

[b]Dead alkali bulrush was included in this acreage

[c]Not a dominant species category in 1989.

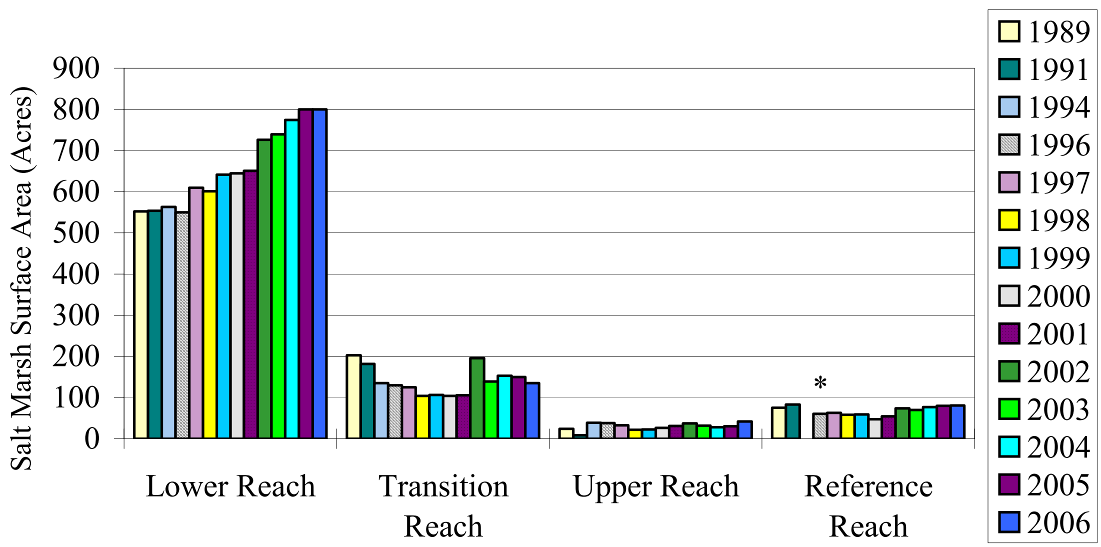
Changes in Surface Area of Salt, Brackish, and Freshwater Marsh Habitats

Salt Marsh. Figure 3 presents the total acreage of salt marsh habitat by year and location (Reach). Salt marsh area increased in the Lower Reach from 1989 through 2005 with most of the increase occurring from 1996 - 1999 and from 2001 - 2005. Much of this increase was due to new marsh formation along the north side of Coyote Creek within segments 3 and 4. Salt marsh area in the Lower Reach remained stable between 2005 and 2006. There has been a significant net change in salt marsh habitat area within the Main Study Area from 1989 to 2006 (197.7 acres)(Table 4). In 2002 we observed substantial gains in salt marsh habitat from both new marsh formation (which has been occurring steadily since 1997) and conversion of brackish marsh habitat to salt marsh habitat. Although we saw some conversion back to brackish marsh in 2003 that persisted into 2006, we also continue to see gains in salt marsh habitat from new marsh formation.

Salt marsh area decreased in the Transition Reach from 1989 through 2001; the decrease in salt marsh area was greatest between 1989 and 1994 (Figure 3). However, a increase in salt marsh habitat occurred between 2001 and 2002 in the Transition Reach. Between 2002 and 2003, a decrease in salt marsh in the Transition Reach occurred, followed by a recovery in the amount of salt marsh in 2004, although not quite to 2002 levels (Figure 3). Between 2004 and 2006, salt marsh habitat has remained below 2003 levels.

Salt marsh area in the Upper Reach decreased between 1989 and 1991, and then increased significantly between 1991 and 1994. Between 1994 and 2006 salt marsh area in the Upper Reach has remained relatively stable with a slight increase in area in 2002 and again in 2006.

Figure 3. Salt Marsh Acreage Comparison between 1989 and 2006, by Reach.



*No data collected in 1994 within Reference Area.

Although there is substantial interannual variation, a net gain of 5.5 acres salt marsh habitat has occurred in the Reference Area between 1989 and 2006 (Table 5). The majority of salt marsh decline in the Reference Reach occurred early in the study period between 1991 and 1996 (Figure 3), including a slight decline in 2000, a rebound in 2001 and 2002, another slight decline in salt marsh area in 2003, followed by a rebound in 2004. Salt marsh habitat has remained relatively stable between 2004 and 2006. The recent increases in 2004 through 2006 are predominantly from new marsh formation near the mouth of Alviso Slough.

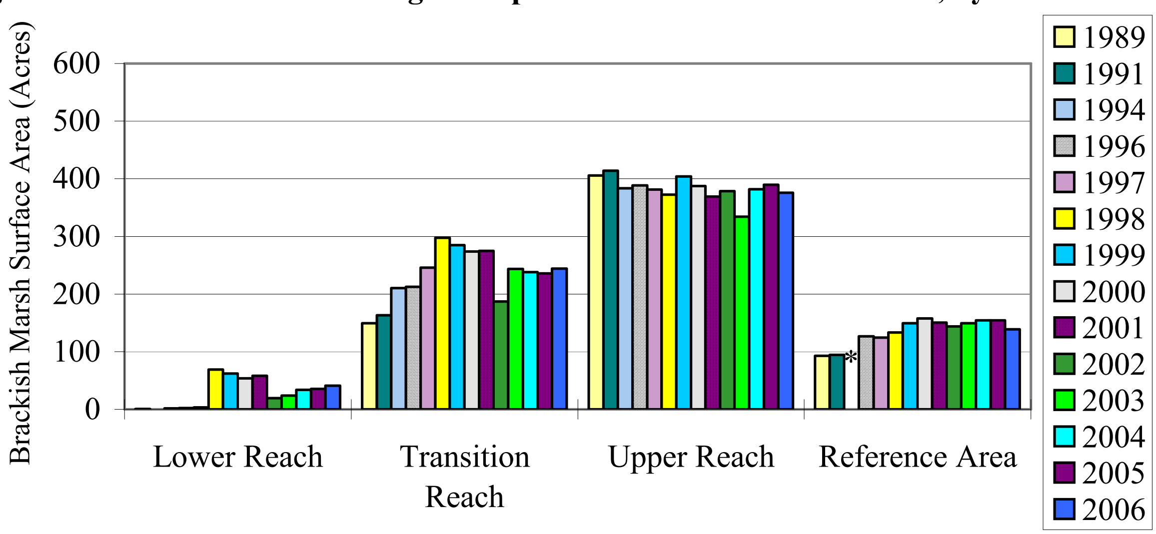
Brackish and Freshwater Marsh. Figures 4 and 5 present the total acreage of brackish and freshwater marsh habitats by year and location. Total brackish marsh area increased by a total of 105.5 acres (19% increase) in the Main Study Area between 1989 and 2006 (Table 4). However, a combination of marsh conversion in the Transition Reach and new brackish marsh formation in the Lower Reach accounts for most of the new brackish marsh in the Main Study Area since

1989. Additionally, alkali bulrush acreage decreased between 2005 and 2006 by 18.8 acres resulting in a net decrease in alkali bulrush between 1989 and 2006 of 27.3 acres. (This decrease is not accounted for by the dead vegetation mapped in 2006, as the dead vegetation totals were included in the alkali bulrush vegetation totals [Figure 4]). While peppergrass increased by over 74.3 acres between 1989 and 2006, this gain also reflects a decrease of 13.3 acres between 2004 and 2005 and a further decrease in peppergrass by 13.6 acres between 2005 and 2006. The 2006 totals also include a gain in 32.3 acres of spearscale.

In the Lower Reach of the Main Study Area, brackish marsh increased dramatically in 1998, after which it declined through 2002, with a notable decrease in 2002 (Figure 4). From 2002 to 2006, brackish marsh has steadily increased but has not reached the levels of 1998. The pattern is similar in the Transition Reach with increases in brackish marsh from 1989 through 1998. Since 1998 there has been a steady trend of decreasing brackish marsh, with a slight increase noted in 2006. The Upper Reach of the Main Study Area has been relatively stable with a trend of increasing brackish marsh from 1989 through 2000. Since 2000, brackish marsh acreage has fluctuated between small gains and losses, with a loss of brackish marsh in 2006 (Figure 4).

The Reference Area experienced a much greater relative increase in brackish marsh habitat during the same 17 years (Table 5). During this period, brackish marsh increased by 46.0 acres (50% increase) in the Reference Area (Table 5). This is due mostly to marsh conversion (from salt to brackish) in the Reference Area. Furthermore, freshwater marsh has increased in the Main Study (primarily in the Upper Reach)(Figure 5) and in the Reference Area during the past 17 years (Tables 4 and 5).

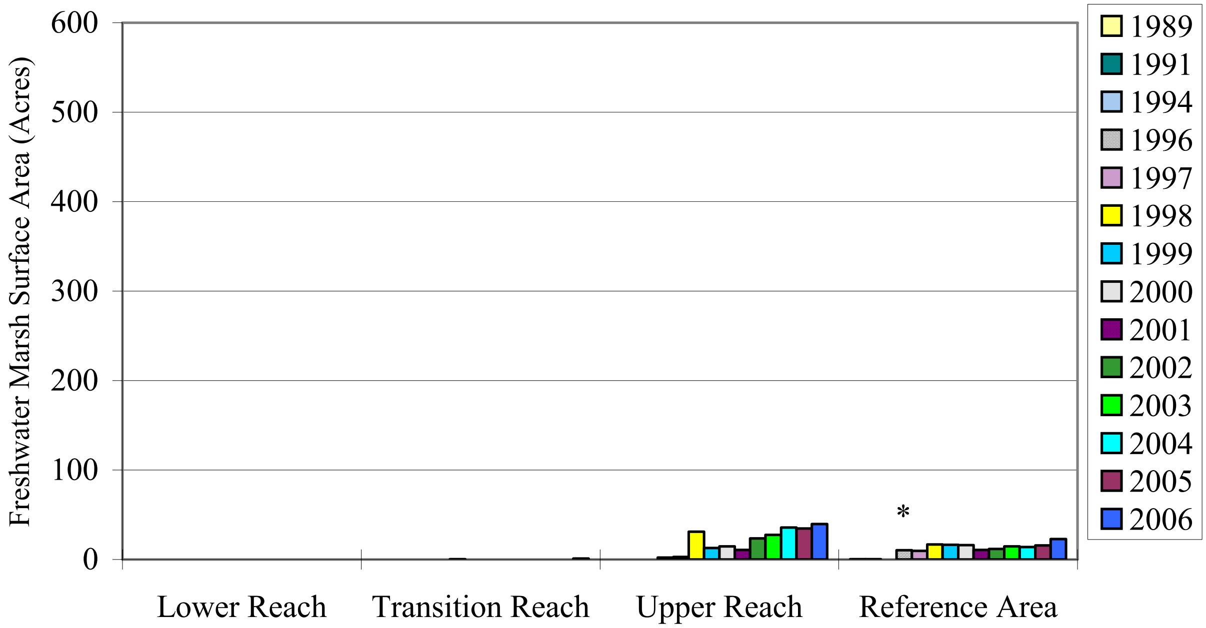
Figure 4. Brackish Marsh Acreage Comparison between 1989 and 2006, by Reach.



*No data collected in 1994 within Reference Area.

The Reference Area exhibited a steady trend of increasing brackish marsh area from 1991 through 2000, but declined between 2000 and 2002 with a slight rebound in 2003 and 2004, and remained stable between 2004 and 2005 (Figure 4). Brackish marsh area declined slightly in 2006. Increases in freshwater marsh habitat since 1989 have only occurred in the Upper Reach and Reference Area (Figure 5).

Figure 5. Freshwater Marsh Acreage Comparison between 1989 and 2006, by Reach.



*No data collected in 1994 within Reference Area.

Habitat Type Conversion

Detailed comparisons by segment location were performed by overlaying the 2006 data on the 1989 data in ArcView. Table 6 provides a summary of the segment locations and shifts in acreage by marsh type from 1989 to 2006. This table differs from Tables 4 and 5 in that the changes are defined by Reach. The area calculations in Table 6 were derived from a segment level analysis (by Reach) in ArcView (Appendix B).

Table 6. Detailed Evaluation of Marsh Type Conversion (in Acres) by Project Reach, 1989 to 2006.

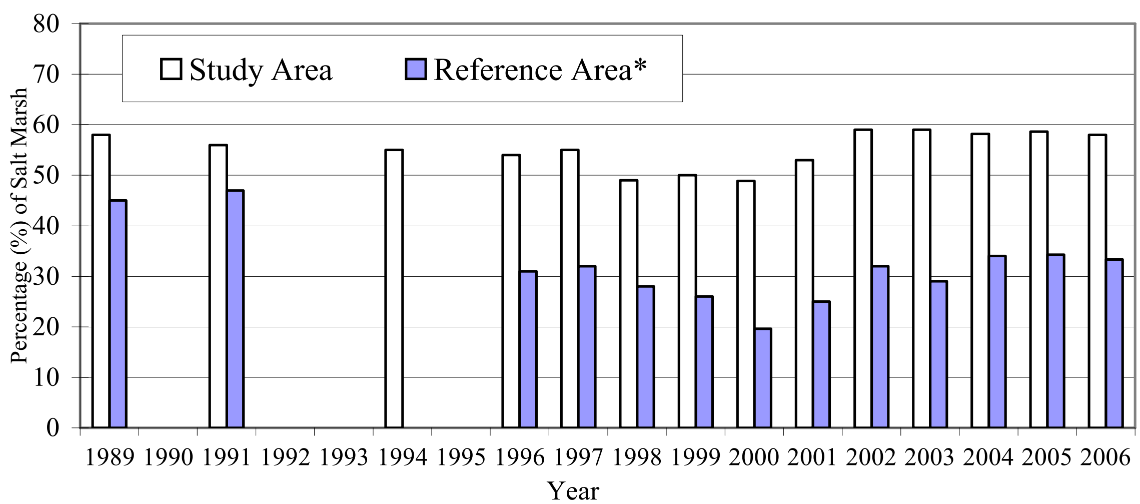
Project Reach	Salt to Brackish or Fresh (Acres)	Brackish to Fresh (Acres)	Brackish to Salt (Acres)	Net Salt Marsh Conversion (Acres)	Proportion of Salt Marsh Converted	Proportion of Total Marsh Converted
Lower	13.48	0.00	0.00	-13.48	1.7%	1.6%
Transition	89.74	0.34	21.21	-68.53	50.6%	18.0%
Upper	16.35	14.19	10.90	-5.45	14.3%	1.0%
Reference	32.10	3.06	3.29	-28.81	35.3%	10.9%

From 1989 to 2006, a total of 119.6 acres of salt marsh habitat has converted to brackish marsh habitat in the Main Study Area, and 32.1 acres of salt marsh habitat converted to brackish marsh in the Reference Area. However, during the same time period, 32.1 acres of brackish marsh has converted to salt marsh habitat in the Main Study Area and 3.3 acres in the Reference Area. Therefore, within the Main Study area 87.5 acres of net conversion from salt marsh habitat to brackish marsh habitat has occurred since 1989. In the Reference Area, 28.8 acres of net conversion from salt marsh habitat to brackish marsh habitat has occurred since 1989. This represents a much greater relative percentage in net conversion of salt marsh compared to the overall amount of salt marsh habitat within the Reference Area (35%) than with in the Main Study Area (9%).

Temporal Changes in Proportional Area of Salt and Brackish Marsh between the Main Study and Reference Areas

The proportion of salt marsh and brackish marsh area relative to total marsh area was compared between the Main Study and Reference Areas from 1989 through 2006 (Figures 6 and 7). This analysis was performed to control for the difference in size between the Main Study and Reference Areas as well as to compare temporal trends in salt marsh conversion between these two areas. The percentage of salt marsh in the Main Study Area remained relatively stable from 1989 through 1997 with a decline between 1998 and 2000 (Figure 6). An increase in the percentage of salt marsh occurred from 2000 to 2002 (stabilizing in 2003 and 2004) with a return to 1989/1991 salt marsh area proportions. The relative decline in the percentage of salt marsh was greater in the Reference Area compared to the Main Study Area (Figure 6) and follows a similar temporal pattern. A decrease in the relative percentage of salt marsh was observed in 2003 for the Reference Area, which was not seen in the Main Study Area. The relative percentage of salt marsh in the Reference Area recovered in 2004, and remained stable in 2005, with a slight decline in 2006. However, the Main Study Area has remained stable throughout the same period, with only a very slight decline between 2004 and 2006.

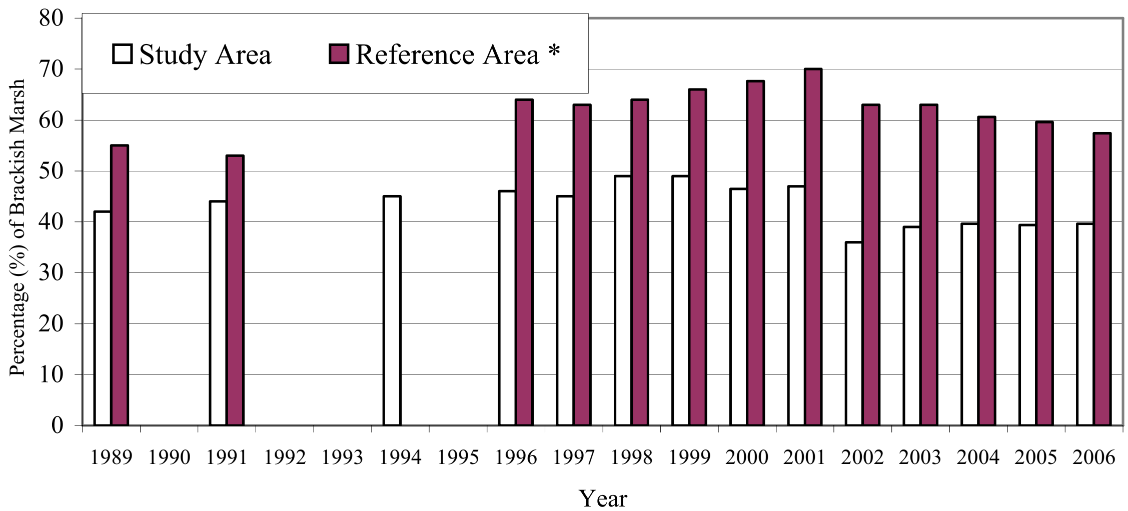
Figure 6. Temporal Comparison of the Proportion of Salt Marsh Area between the Main Study and Reference Areas.



*No data collected in 1994 within Reference Area.

The proportion of the Main Study Area that is brackish marsh remained relatively constant between 40% and 50% until 2002 (Figure 7). The 2002 sampling showed the first significant decrease in the percentage (10%) of brackish marsh since the study began. The percentage of brackish marsh increased in 2003 and remained stable through 2006 (Figure 7). The Reference Area showed a steady increase in brackish marsh until 2001; a larger increase in the percentage of brackish marsh was observed in the Reference Area than in the Main Study Area (Figure 7) between 1989 and 2001. This increase in the proportion of brackish marsh area to total marsh area in the Reference Area occurred primarily between 1991 and 1996 and between 1998 and 2001 (Figure 7) during the same time that the percentage of salt marsh declined (Figure 6). The percentage of brackish marsh in the Reference Area decreased in 2002 and remained stable in 2003. From 2003 to 2006, the percentage of brackish marsh has been declining.

Figure 7. Temporal Comparison of the Proportion of Brackish Marsh Area between the Main Study and Reference Areas



*No data collected in 1994 within Reference Area.

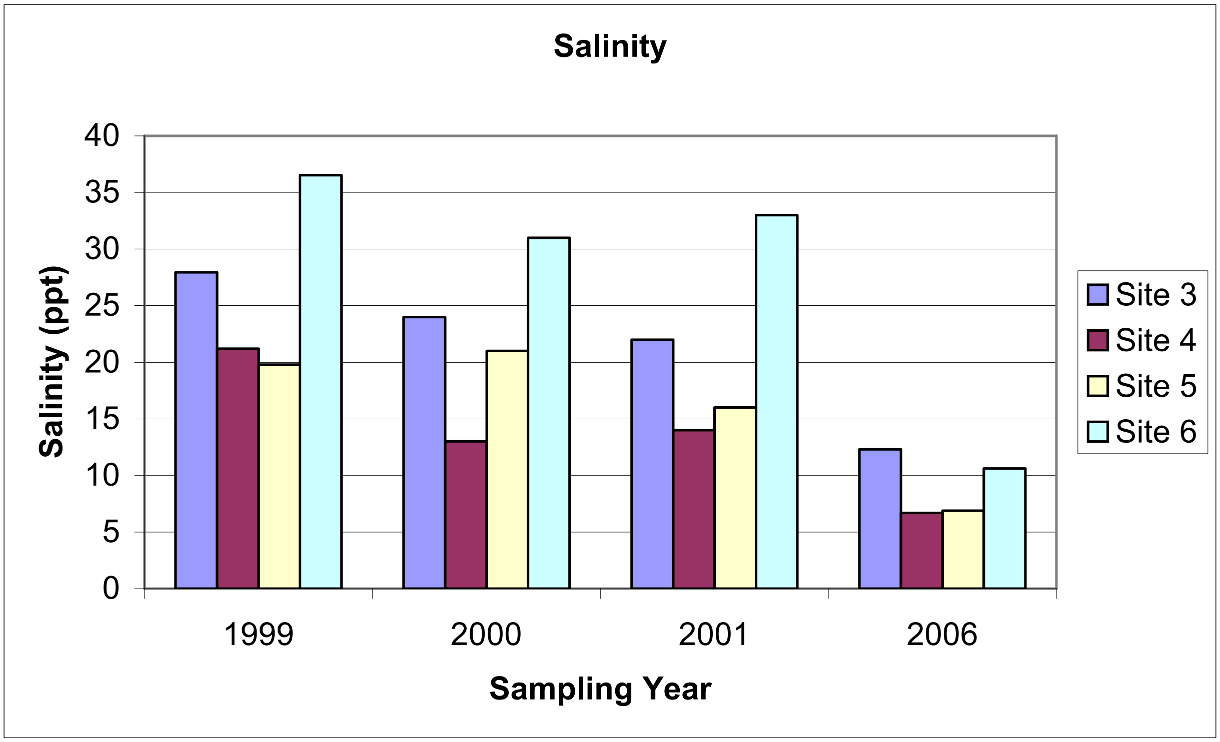
EDAPHIC CHARACTERISTICS

Edaphic (or soil) properties are important in understanding the physical parameters that can determine the spatial distribution of plant communities. Results of limited edaphic sampling in the Reference Area in response to observed vegetation die-off are included here. Data analysis for all parameters (bulk density, pH, conductivity, and salinity) are included in Appendix G (Figures G2-G13).

Interstitial Salinity

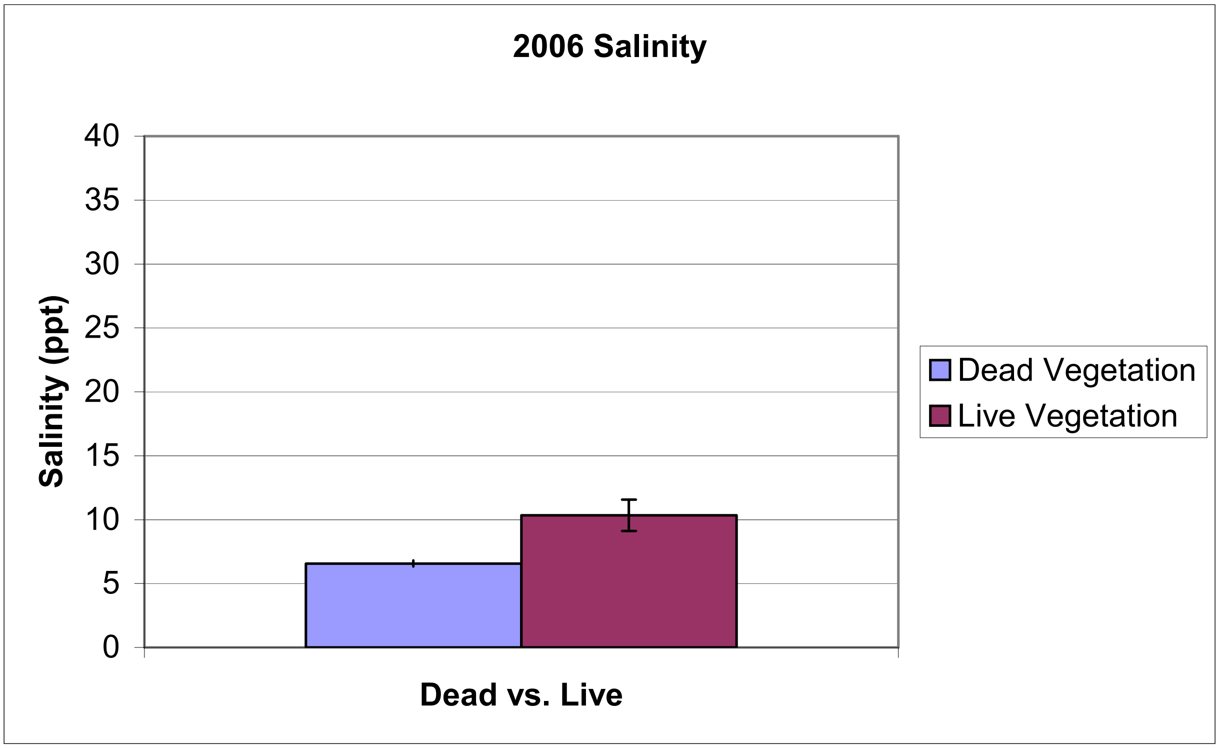
Interstitial salinity data for 2006 was compared with four permanent sites previously sampled in 1999, 2000, and 2001 (Figure G-1 and Figure 8) (H. T. Harvey & Associates 2001b). Sites 4 and 5 are further upstream in Alviso Slough and over all four sampling periods have predictably had lower salinities than Sites 3 and 6. Over all four sampling periods, Site 3 has consistently been less saline. Site 5 became slightly more saline in 2000, with decreased salinity in 2001, and decreased salinity again in 2006. Sites 4 and 6 became less saline in 2000, but more saline again in 2001. Because only one sample was collected at each site, the ability to statistically analyze the data was limited. However, all sites demonstrate a trend in decreased salinity between 1999 and 2006, and the 2006 data indicates lower salinity than any of the previous three sampling periods.

Figure 8. Interstitial Soil Salinity at Four Sample Locations Located Within the Reference Area in 1999, 2000, 2001, and 2006.



The soil cores collected in 2006 were analyzed to compare salinity levels in areas of dead vegetation versus live vegetation (Figure 9). There was a significant difference in salinity between the areas of dead vegetation versus the areas of live vegetation ($p = 0.04$, $\alpha = 0.05$). Salinity in the areas of dead vegetation averaged 6.57 (± 0.24) ppt ($n = 3$). Salinity in the sites with live vegetation averaged 10.33 (± 1.22) ppt ($n = 3$).

Figure 9. Soil Salinity Comparisons between Dead versus Live Vegetation in 2006.



Secondary Indicators of Inundation

Soil cores for all six sites were analyzed for the presence of redoximorphic features as secondary indicators of inundation. Such features may include iron and manganese, mottling, sulfitic odor and gleyed soil colors. All of the soil cores were gleyed, exhibited low chroma, and contained oxidized root channels, although to varying degrees. No apparent differences were found between soil redoximorphic features found in marshes supporting live versus dead samples. From the limited number of samples taken in September it is difficult to determine whether inundation was a factor contributing to alkali bulrush die-off.

Soil Bulk Density and pH

Bulk Density. In 2006, analysis of soil bulk density showed no discernible differences between dead versus live sites (Figure G-2). In comparing bulk density over the 3 sampling periods (2000, 2001 and 2006 [no data was reported for 1999]), there were no apparent differences between the years 2000 through 2006 (Figures G-6 and G-7). There were also no apparent differences in bulk density between sites for the same three sampling periods.

pH. In 2006, there were no differences in pH between dead versus live sites (Figure G-3). In comparing pH between the sampling periods 1999, 2000, 2001, and 2006, there were no differences between years (Figure G-7), or between sites (G-11).

DISCUSSION

MARSH CONVERSION

Between 1989 and 2006 there was an overall net conversion in the Main Study Area from salt to brackish marsh of 87.5 acres and 28.8 acres of salt to brackish marsh conversion within the Reference Area (Table 6). However, between 2005 and 2006 there was a decrease in the overall salt marsh conversion (increase in salt marsh) in both the Main Study Area and the Reference Area (Table 7) (H. T. Harvey & Associates 2005).

Table 7. Comparison of Salt Marsh Conversion between 2005 and 2006.

Project Reach	Net Salt Marsh Conversion in Acres (1989 – 2005)	Net Salt Marsh Conversion in Acres (1989 – 2006)	Net Salt Marsh Conversion in Acres (2005 – 2006)
Lower	-14.54	-13.48	1.06
Transition	-71.22	-68.53	2.69
Upper	-8.51	-5.45	3.06
Reference	-31.49	-28.81	2.68

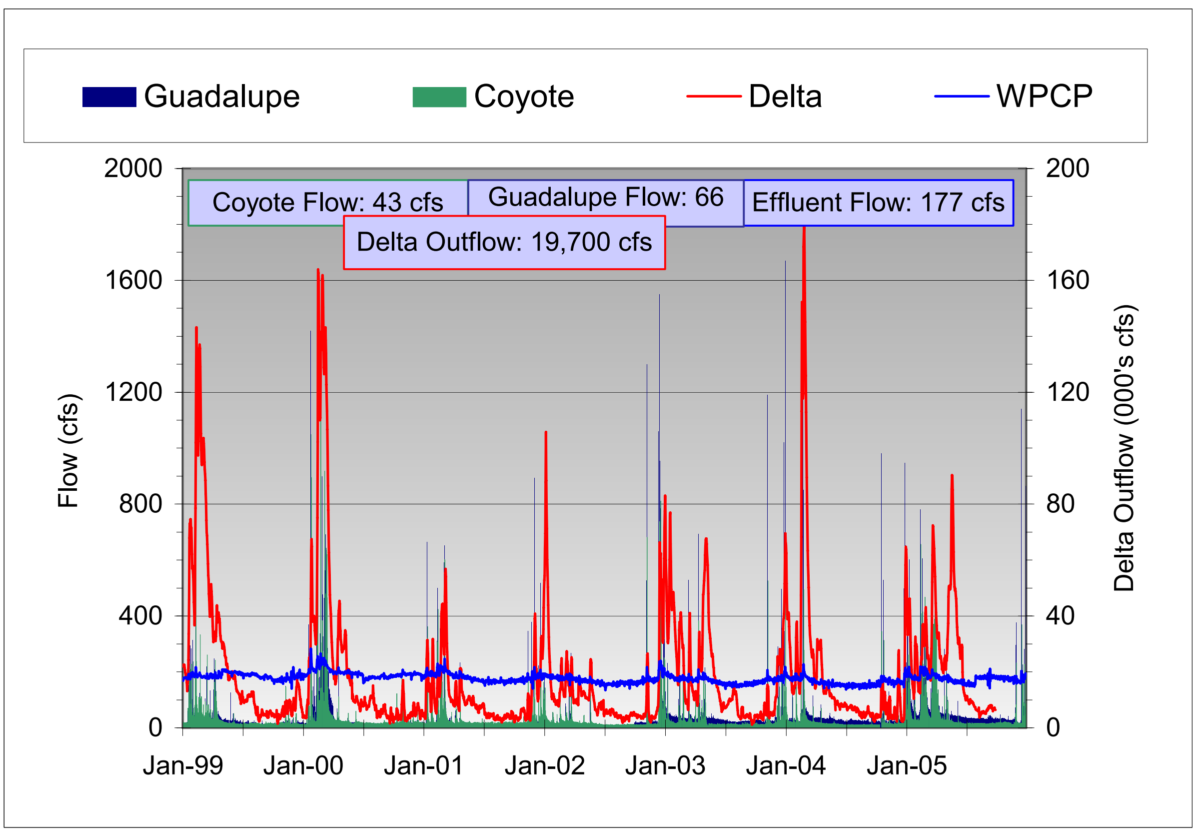
In addition to these minor changes in marsh type between 2005 and 2006, there was also a shift in species composition within the brackish marsh component. An increase in total acreage of spearscale between 2005 and 2006 was noted in both the Main Study Area (32.3 acres) and the Reference Area (9.9 acres). There was also a decrease in peppergrass in the Main Study Area (13.6 acres) and in the Reference Area (0.6) acres (Tables 5 and 6). These vegetation shifts in 2006 are likely related to the vegetation die-off and increased late-season precipitation in 2005 and 2006. In fact, new areas of spearscale were mapped where alkali bulrush die-off occurred in Segments 13 in the Main Study Area and in Segment 28 of the Reference Area (Figures A3 and A4).

The only segments where conversion (either from salt to brackish or brackish to salt) did not occur between 1989 and 2005 were those segments located immediately adjacent to San Francisco Bay (Segments 1, 2 and 8). In 2006, a small area of salt marsh converted to brackish marsh at the northern end of Segment 1. These marshes are likely outside of the immediate influence of Coyote Creek and Alviso Slough flows, but are instead influenced directly by San Francisco Bay hydrology. The lack of salt marsh conversion adjacent to San Francisco Bay and in the bayward portion of Mowry Slough (Segment 8) within the Main Study Area may indicate that the factors affecting marsh conversion are limited to the Coyote Creek and Alviso Slough Reaches. The two factors that differ between these areas are freshwater input and on-going changes in channel morphological.

The WPCP discharges have been relatively constant since 1989 (~180 cfs ±30%), while salt marsh conversion has fluctuated between years. It is likely that much of the overall marsh conversion is driven by large-scale influences (both environmental and anthropogenic) that are affecting the entire system. These include local and regional freshwater inputs, historic landscape-scale changes such as salt pond construction (SFEI 1999) and subsequent changes in channel morphology. Rainfall patterns and sea level rise likely also contribute to vegetation shifts, as well as changes in relative tidal height from historic groundwater pumping between 1919 and 1967 that resulted in widespread subsidence in the Alviso area.

In addition to WPCP effluent flow, vegetation distribution may also be driven by regional freshwater inputs. Discharges from Guadalupe River (Alviso Slough), Coyote Creek and the Sacramento/San Joaquin Delta also play a role in marsh conversion and formation. Figure 10 shows the freshwater inputs from each of these systems and demonstrates the relative contribution of each of these inputs to the Bay (courtesy of the City of San Jose). While the WPCP effluent dominates the dry season flows, freshwater input from the local drainages (Coyote Creek and Guadalupe River) during the winter are much larger, and are dwarfed by the overall influence of the inputs from the Delta which can alter salinities bay-wide. The timing and variability in flows (and therefore salinity) from each of these inputs also influence the vegetation distribution in the South Bay. For example, while the average rainfall period March through May in 2006 represents a 265% increase in average rainfall (10.6 inches versus 4.0 inches), WPCP effluent flow averaged 194 cfs, representing an increase of only 14% above the average effluent flow over the last two years (170 cfs).

Figure 10. Local and Regional Freshwater Inputs into South San Francisco Bay.



NEW MARSH FORMATION

New marsh formation between 2005 and 2006 has been minimal compared to previous years; approximately 5.8 acres of new marsh occurred in the Main Study area. New marsh formation in the Lower Reach occurred rapidly beginning in 1997 and continued through 2005. Much of this new marsh formation occurs as mudflats along Coyote Creek near Calaveras Point. These mudflats likely reached an elevation that would support wetland plant species in 1996/97 and were rapidly colonized thereafter. The large mudflat in Coyote Creek just upstream of the confluence with Alviso Slough is now at an elevation that supports wetland plant species and this area is dominated primarily by cordgrass.

There has been a net increase of 343.5 acres (26%) of overall marsh area (new marsh formation less marsh loss) since 1989 in the Main Study Area. Historically, the majority of this increase is due to sediment accretion along slough and river channels and subsequent vegetation colonization to form new marsh area. The majority of new marsh formation is located in the Main Study Area in the Lower Reach (Segments 2, 3 and 4 near the mouth of Coyote Creek, Segment 8 near the mouth of Mowry Slough, as well as Segments 22 and 23 near the mouth of Alviso Slough) (Figure B-5). New marsh is also located along Coyote Creek in Segments 9 and 10. The majority of new marsh formation in the Reference Area is located in Segment 30 near the mouth of Alviso Slough (Appendix B, Figures B-5 through B-8).

The relative lack of new marsh formation in 2006 compared to previous years could be due to any number of factors. However, it is of interest to note that it coincides with the breaching of the Island Ponds earlier this year. The increase in tidal prism resulting from the opening of these three former salt ponds to tidal action is anticipated to result in some scour of the existing mudflats and possibly some fringing marshes. In subsequent years we will continue to evaluate the potential affect of the levee breaching on new marsh formation in the South Bay (see below for further discussion on the Island Pond breaches).

VEGETATION DIE-OFF

Large patches of alkali bulrush die-off were observed in many of the Reaches in 2005, most notably in Alviso Slough. In 2006, significant areas of vegetation die-off were observed both in alkali bulrush and pickleweed communities within the Main Study Area and the Reference Area (Appendix A; Figures A-2, A-3 and A-4). This plant die-off in both 2005 and 2006 may be related to prolonged inundation and decreased soil salinity resulting from late season rains during the germination period (Figure 11). Late season rains were examined separately this year as the soil salinity during the germination period can influence marsh vegetation distribution.

The small-scale edaphic study performed in the Reference Reach in September 2006 found that salinity levels at the four permanent sample stations in the Reference Reach has been declining since 1999 (Figure 8). In addition, salinity in the areas of dead alkali bulrush was lower than in the areas of live alkali bulrush (Figure 9). There has been a steady increase in mean sea level since 1999 with higher than average mean sea level in both 2005 and 2006.

While alkali bulrush distribution does not appear to be solely related to interstitial salinities, its distribution is likely related to a combination of environmental stress factors including interstitial salinities, interspecific competition and depth and duration of flooding over the marsh surface. This combination of environmental stress factors may be dramatically altered by increases in freshwater discharge, changes in rainfall patterns, changes in the depth and duration of flooding on the marsh, or some combination of these factors. Interannual variations of mean sea level show an increase in 2006 (Figure 12). With the observed salinity and rainfall patterns, this combination of stressors may have produced the observed marsh vegetation die-off.

Figure 11. Total late season rains (March, April, and May) for San Jose, California from 1986-2006 (National Weather Service station at San Jose).

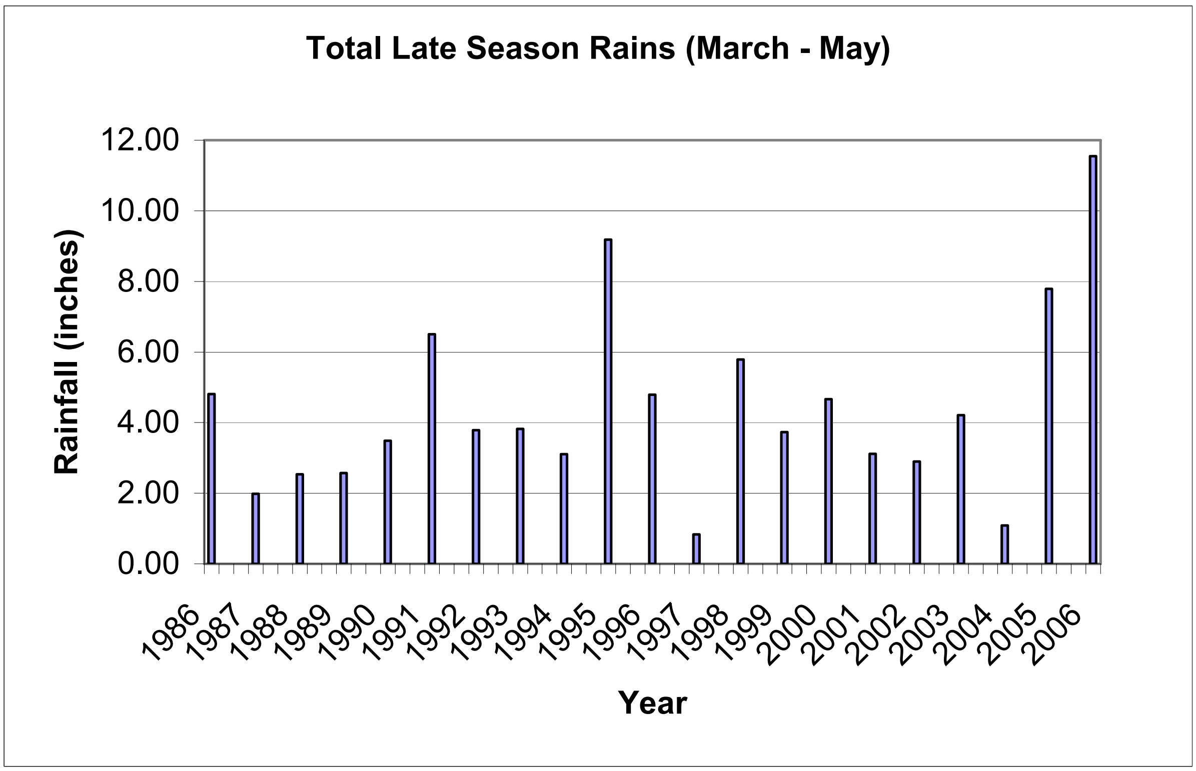
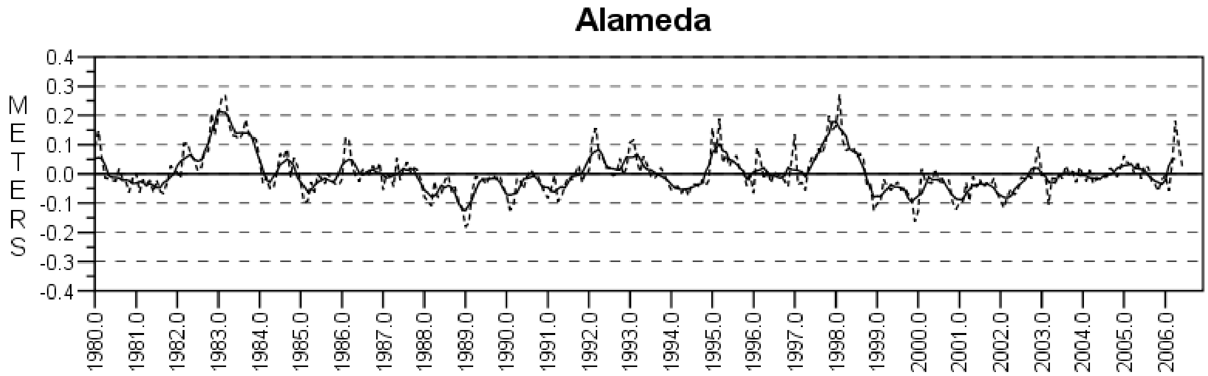


Figure 12. Interannual variation of mean sea level for Alameda, California 1980-2006 (http://tidesandcurrents.noaa.gov/sltrends).



Note: The plot shows the monthly mean sea level with the average seasonal cycle and the linear trend removed (dashed curve) and the 5-month average (solid curve). The data are taken at Alameda and the graph is indicative of the trends in San Francisco Bay. However, it should be noted that the tidal amplitude in the South Bay is greater than the values reported above for Alameda.

The limited study performed in September 2006 only included soil salinity, pH, and bulk density at the end of the growing season. The samples collected indicate that low salinity was likely a factor in the die-off. Additional measurements of water levels and redox potential performed during the winter and/or spring could help to determine how the timing and depth and duration of flooding are affecting these marshes.

ISLAND POND BREACHES

As part of the Initial Stewardship Plan for the SBSP Restoration Project, three former salt ponds (Island Ponds 19, 20, and 21) adjacent to Segments 14, 15, and 21 in the Main Study Area were breached in the Spring of 2006. The breaching of these ponds resulted in increased tidal prism in the Main Study Area, which could result in vegetation shifts unrelated to the WPCP discharges. Areas of newly formed marsh should be monitored closely, as they will likely be the first marshes to be affected by any increases in tidal scour related to this restoration. Related studies, including sedimentation rates and marsh scour analysis are currently underway and will further elucidate the impact of these changes. However, vegetation mapping for 2006 indicates that there has been no detectable change in species distribution due to the breaching of these ponds

CORDGRASS MAPPING

The salt marsh habitat in the South Bay consists primarily of pickleweed, and two species of cordgrass including California cordgrass*,* and smooth cordgrass (*S. alterniflora*), and its hybrids (*Spartina alterniflora* [hybrids]), a non-native species from the east coast. Control and management of *Spartina alterniflora* [hybrids] falls primarily within the scope of the Invasive Spartina Project and their agency partners U.S. Fish and Wildlife Service and Santa Clara Valley Water Control District (California State Coastal Conservancy and U.S. Fish and Wildlife Service 2003). The Invasive *Spartina* Project and the Santa Clara Valley Water Control District's monitoring of these species shows an increase in *Spartina alterniflora* and *Spartina alterniflora* [hybrids] in the far South Bay from approximately 1 acre in 2000/2001 to approximately 8.7 acres in 2005 (Santa Clara Valley Water District 2006).

It is often difficult to distinguish between the cordgrass species and the hybrids, especially without the ability to enter the marsh and examine the plants closely. Therefore, during mapping it is difficult to distinguish between these species; consequently they were mapped collectively as cordgrass. However, based on morphological observations made in the field, we assume that the native species as well as the hybrids are both present in the study area.

In 2005, two samples collected in the field and genetically tested were found to be *Spartina alterniflora* and *Spartina alterniflora* [hybrids], suggesting that these cordgrass species are likely colonizing the study area. In 2006, we did not attempt to differentiate between non-native and the native cordgrass species. However, visual observations of what appear to be large stands of *Spartina alterniflora* [hybrids] were noted higher in the marsh plain at Calaveras Point and along Segments 9, 22, and 23 in the Main Study Area. Increases in cordgrass in general were also observed along the edges of Segments 1 and 2, and higher in the marsh plain in almost all salt marsh dominated segments.

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